Research Article

Innovating with History: How an Archival Intervention Diminishes Snow's "Dangerous" Divides

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What we now refer to as the two cultures divide has shown itself unexpectedly among engineering undergraduates. The notion that history is something that happens apart from the world of technology—and that only technical constraints, and not politics, ideologies, economics, law, or other social concerns, impact the development of technology—is not universal among undergraduate engineers, yet it is heard often enough to make us realize that, as much as C. P. Snow said that the humanities are willfully ignorant of science, the sciences have a corresponding tendency to believe humanistic inquiry is outside their purview.

This article describes how an instructor and an archivist at New York University Tandon School of Engineering[1] implemented an archival research experience in an undergraduate general education elective. Given that some engineers profess a respect for history and the success of classroom interventions designed to engage engineering students in how history can inspire innovation, one can say that this divide is a habitual way of thinking about history more than it is an inevitable demarcation. The challenge is to find the instructional method that helps students to realize that there is more than one way to think about history and to be skeptical about their preconceptions of what the field has to offer. Thus, our motivation was to encourage science and engineering students to think critically about history, helping them to expand their definition of history and, hopefully, to broaden their understanding of the process of inventing, innovating, and disseminating technological devices and scientific knowledge.

In an earlier experience (Anderberg, 2014), the authors engaged in an intensive archival research project that involved a significant amount of time for the instructor, the archivist, and the students. In the design of the current exercise, we were interested in creating a less demanding experience that could serve as a gateway to further projects. Even so, because the present, more minimal exercise was still disruptive to a lecture-based course, we sought a means of assessment: to what extent could we say that this experience was valuable, and how could we use this information to improve our effort the next time around?

Our experience shows that even a limited, hands-on experience in the context of a general education elective can encourage engineering and science students to think critically about the role of history in the fields of science, technology, engineering, and mathematics (STEM). One of the challenges in this enterprise was to reposition student assumptions about history: in order for them to think critically about the value of historical analysis for STEM, we had to convince them that the humanities and STEM do not exist in separate domains. The students' written responses show that this archival experience was successful. Although the effect was nowhere near universal, one would not expect that any classroom experience would provide uniform results. The archival experience reinforced the course's theme of

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innovation; in the archive, students were inspired to use critical thinking to gain a more thorough understanding of the complex interplay among science, technology, and society required to bring new ideas to fruition. In addition, several students wrote about how this critical-thinking experience had brought them closer than ever before to the world of actual innovation. Given that one challenge to retaining talent in STEM, particularly among women and underrepresented minorities, is their sense that the college experience is removed from the professional world, this project might be especially beneficial to STEM students in their first or second year, before they are ready to engage in the more professionally-oriented, major-specific courses that typically take place in the junior and senior years.

Introduction

The two-culture dichotomy described by C. P. Snow (1959) was between what he called literary intellectuals and physical scientists. Although Snow admitted to being in conversation with both, he noted that each group had its own distinct culture. While the physical scientists were looking toward the future and basically optimistic, the literary intellectuals were anti-technology pessimists. He went as far to say that the artistic movements of the first half of the twentieth century made their audiences antisocial, causing a deepening of the divide. The literary intellectuals, with their historical mindsets, were nevertheless the ones in control of managing the world's resources. Snow's solution to this "intense specialization" (p. 19) was education, insisting that Luddite literary intellectuals needed to understand the industrial revolution and the management processes that produce consumer goods. Snow's proposed educational mission, notably, would be to bring science to the literary intellectuals.

Although Snow spoke of the hostility between the two sides, for the most part, he seemed concerned with how the literary intellectuals, a category he expanded to include all "non-scientists," are isolated from the scientists, and not the reverse. The one-way path of the divide Snow decried is clear in the anecdotes that pepper the lecture. In the company of the literary elite expressing their dismay about the supposed illiteracy of scientists, he said:

> I have been provoked and have asked the company how many of them could describe the Second Law of Thermodynamics. The response was cold [. . .]. Yet I was asking something which is about the scientific equivalent of: *"Have you read a work of Shakespeare's?"* (p. 14)

Later in the lecture, Snow noted that the ignorance extends to the applied sciences, the industrial process he said is "the social plasma of which we are part." Too few literary intellectuals, he claimed, know anything about how things are made.

> How many people know anything about productive industry, old-style or new? What is a machine-tool? I once asked a literary party; and they looked shifty. Unless one knows, industrial production is as mysterious as witch-doctoring. Or take buttons. [. . .] I would bet that out of men [*sic*] getting firsts in arts subjects at Cambridge this year, not one in ten could give the loosest analysis of the human organization which it needs. (p. 28)

A caricature of an engineering student in a history elective would describe a student who thinks that history is about the precise understanding of past events. There are many students at the School of Engineering who are adept at this version: students who profess an interest in history and who have had good backgrounds in their high school education that allow them to faithfully represent accurate timelines of history and to explain the wide social context that surrounds particular events. Other students, however, do not have this background, especially if their high schools devoted more resources toward science and engineering. These students can be seen on a continuum of understanding the basic history one needs to speak generally about the progress of world, European, and/or American history. Some students are quite good at explaining historical incidents, yet others know very little. This pedagogy could be thought of as the *introduction-to-history* approach.

One way to teach history in this environment would be to try to catch up students who are seen as behind and, at the same time, provide challenges to those who are at an advanced state. This approach seems commonsensical, and yet it has distinct disadvantages. Primarily, because it is based on what some students were exposed to previously, a select group will have an advantage. The introduction-to-history approach serves to ratify the educational background (and thus social status) of some students. Also important, though, is the idea that all students in the introduction-to-history pedagogy are relying on historians for their information. In this basic approach, in other words, it is not so important that the students (or engineers) conduct history because there are other professionals who can do it for them, and it is assumed that engineers need little more than the general histories made for a wide audience. In this way, the introduction-to-history approach exacerbates existing divides.

An additional problem related to the introduction-to-history approach is that science and technology studies (STS) scholars have long noted that its study of heroic moments and inevitable progress does not reflect the process of innovation well. Trevor Pinch's (2005) study of the Moog synthesizer, for instance, shows how the device's ultimate use was not anticipated by its creators and instead was constructed, or we might say invented, in the process of selling it to customers. Likewise, Wiebe Bijker's (1992) analysis of fluorescent lighting demonstrates how the definition of the technical solution was unstable during its design and prototyping stage, and in use the fluorescent light took on its mature form only after designers inserted lessons learned from the diffusion of the technology back into the design process. STS theorists like these have made many observations in disparate fields to show that there is rarely a smooth, lineal path of innovation, invention and diffusion of a technological solution. A common rhetorical move, made by Arnold Pacey (1991) and others, is to assert that there is no such thing as an independent technology: a technology is a way of carrying out activities, a cultural practice, and the devices we see around us are only manifestations of social organization. History, in this context, is plural and seeks to illuminate the interactions between innovators and larger social structures.

In spite of the complex, heterogeneous paths taken to develop technological solutions, STS scholars have noted that what we have been calling the introduction-to-history model seems endemic, even to those most intimately involved with the development of technology. This smooth, lineal path is sometimes called a whig, deterministic, or internalist approach to the history of technology. According to this kind of thinking, technology progresses according to its own logic with no regard to the social, economic, legal, or other frameworks around it. Geof Bowker (1992), for instance, wrote how whig history is used in patent applications so that they can withstand the scrutiny of patent litigation. The way invention stories are told for patent applications is that a new idea came to the inventor's head unexpectedly, without connection to other inventions, and that it drastically and immediately improved the way in which work gets done. When patent claims are successfully litigated, the notion of a whig history is reinforced. This way of thinking seems akin to the two cultures divide, in that the complex process of history is made irrelevant to commercial and litigious success; history is what happens in statehouses and in villages, but not in drafting rooms or machine shops.

A different pedagogical approach, however, is to address a weakness common to students who have some background in history and those who do not: neither group understands well the challenges to how history is made nor has a deep appreciation of how engineering professionals might benefit from the study of history. This pedagogy can be called the *constructing-history* approach. Consider, for example, the work done by Shapin and Schaffer (2011): their close attention to the material of history in *Leviathan and the Air-Pump* reveals the extent to which the path of innovation is marked by "heterogeneity, variation in belief and judgment, [and] controversy" (p. xliii). Instead of the lineal path that describes, for instance, Boyle's disruptive invention of the air pump and the start of the scientific revolution, Shapin and Schaffer ask us to see the less-than-distinct demarcation between the old and new. They eschew an "insider's" account, which would suggest that science is motivated by the desire to produce reliable data from experimental results because, by definition, today that is how we distinguish the age of science from the earlier age. Instead, these authors seek to present the way in which the debate was conditioned by social expectations. Far from portraying an inevitable notion of progress, their study shows to us that it takes more than identifying a technical opportunity to make innovation happen.

Our current effort to improve the effectiveness of scientists and engineers with an archival exercise might seem counter to Shapin and Schaffer's comment that the standards governing the practice of history should be developed by historians and not, as they say, politicians, artists, and scientists. "These other groups might expect historical studies to celebrate their lineage, to offer up object-lessons of proper conduct, or to find foreshadowing of the bright present in the dark past" (p. xvii). At the same time, we suggest that undergraduate scientists and engineers can benefit professionally from lessons in historical thinking, though we have sought to design experiences that direct their attention away from lionizing, linear histories that create origin stories of inevitable progress. Instead, we suggest that activities that engage students directly with the material of history and that demonstrate what Shapin and Schaffer have shown to be the complex contradictions and multiple perspectives of historical actors are an invaluable educational experience. Cultivating critical thinking about history in students by helping them to see that their STEM training and ambitions are not antithetical to the professional standards of history was a central goal of this project. In this way, we hope to ease the divide between the intellectuals and the scientists noted by Snow.

Literature Review

We are mindful that our effort to bring archival experiences into the classroom is part of a long effort. As far back as 1975, the Society of American Archivists (SAA) established the Committee on the Wider Use of Archives (Pederson, 1978). The following year, the committee circulated a survey to 400 institutional members of SAA, including historical societies, government archives, library special collections, and university archives, to determine what form of archival outreach programs were underway across the United States. At this time, the term "outreach" was such a new concept that it always appeared within quotations. Although one goal of the survey was simply to consolidate programming information from across the country, the committee also considered the survey itself a form of outreach to archivists, encouraging a shift in thinking about archives as the protected records of a few to "history-in-the-raw" as a right of all citizens (p. 155). Even though outreach initiatives may not address STEM education specifically, the effort to create hands-on experiences for college students dates back at least 40 years.

This movement to democratize archives slowly permeated academia. By the 1980s, the National Archives and Records Administration (NARA) led the way in creating programming that introduced undergraduates, rather than graduate students, to primary source materials (Carini, 2007, p. 42). By the late 1990s and early 2000s, the idea of archival outreach to humanities undergraduates was popular within archival literature (Carini, 2007; Johnson, 2006; Krause, 2008; Mazak & Manista, 1999; Mitchell, Seiden, & Taraba, 2012). Despite this trend, outreach to STEM undergraduates is still not commonplace. Although interdisciplinary studies are increasingly popular in the United States (Haynes & Leonard, 2010, p. 645), the lack of archival outreach to STEM scholars echoes C. P. Snow's lament from half a century ago about the two cultures divide in intellectual life (Snow, 1959, p.4). As Snow warned, "the number two is a very dangerous number . . . . Attempts to divide anything into two ought to be regarded with much suspicion" (p. 9). Even the now-common assertion that the archives are the "laboratory of the humanities" (Society of American Archivists, 2015, n.p.) implies a division of spaces allocated to scientists and humanists: scientists work in the lab, but humanists work in the archives.

In the case of archival outreach to STEM undergraduates, dangerous dichotomies like Snow's extend beyond a science/humanities split into a division between two cultures of the university: the teaching faculty and the members of supporting departments. For example, while it is acknowledged that the library supports scholarly research at the university, it may be less accepted that librarians play an active role in teaching students, as teaching is a primary role of professors. As Krause (2008) acknowledged, even in articles about professor-archivist collaboration there is a "relative absence of the role of the archivists or curator in providing instruction, reference, and facilitating access to the collections" (p. 234). Only in rare circumstances, such as Mazak and Manista's 1999 article about collaborative teaching at Michigan State University, is there "the conscious acknowledgement of the archives staff as a critical factor in the success of the collaboration" (p. 234). Therefore, integrating archival research into STEM curricula crosses not one, but two barriers. Overcoming these obstacles requires a true partnership between the professor and the librarian or archivist, with a focus on meaningful outcomes for STEM students.

Although collaborative outreach to STEM undergraduates is not mainstream, there is evidence of increased efforts in this area. In 2008, Hankins, a librarian at the Cushing Memorial Library and Archives, described her outreach to a botany professor at Texas A&M University. What could have been a one-off visit to the reading room instead developed into an ongoing collaboration. Five years after the initial outreach, the archival collections of botanical sketches and herberia were firmly embedded in the botany curriculum. Similarly, when a New York University archivist recognized that her collections could provide primary source content for Web design students, she worked with the Computer Science department to develop the undergraduate course "Computing in the Humanities" (Bunde & Engle, 2010). These two examples show that integrating archival collections into science courses has the potential to transform textbook-based teaching into memorable, tangible learning experiences, while keeping with a department's overall vision and goals.

These types of collaborations can be course-specific and time-bound or flexible and ongoing. At California Polytechnic State University (Cal-Poly), a materials engineering professor, a biology professor, and a librarian team-taught an undergraduate course on nanotechnology, biology, ethics, and society (Vanasupa, Stolk, & Herter, 2009, p. 75). The course consisted of daily, guided readings from primary sources, with a variety of assignments—quizzes, creating interconnected diagrams to illustrate concepts, and debating issues in teams. While this seminar may not happen yearly, the idea of using primary sources to generate a more in-depth understanding of scientific concepts is one that can be applied to any number of courses. On the other end of the spectrum is University of Colorado Boulder's Herbst Program of Humanities for Engineers: a long-standing, institutionally-supported program which embraces the idea that "special collections instruction need not be limited to a single discipline" (Brown, Losoff, & Hollis, 2014, p. 197). Within this program, special collections librarians and professors routinely collaborate to create courses that not only "promote active, student-driven learning" but also "improve undergraduate science education" (Brown et al., 2014, p. 197). While such a robust program may only be a dream for smaller institutions, this kind of ongoing collaboration provides a model for archivists and instructors who teach undergraduate STEM students.

In these examples of outreach to STEM undergraduates, course type, focus, and scale of engagement vary, but all of these efforts produced positive, measureable results for students, professors, and librarians or archivists. For example, at the end of the course at Cal-Poly, the professors and librarian found that students "reported that *understanding the broader context* increased their interest in science and *motivation* to learn the material" (Vanasupa et al., 2009, p. 76). At New York University, where the Computer Science department "encourages faculty to create courses in Web programming" and project-based courses, the archivist satisfied a need for the faculty by providing content for a project-based course (Bunde & Engel, 2010, p. 155). Finally, CU-Boulder reported that integrating primary sources into the engineering curriculum was "transformative . . . . It demonstrated a new methodology for engaging science undergraduates by using special collections as a discovery space" (Brown et al., 2014, p. 205). Although these successful projects highlight the potential of integrating primary source materials into undergraduate STEM classes, archival outreach to science and engineering students is still far from mainstream.

The history of archival outreach is a reminder that connecting with new and diverse patron populations can be a slow process. Before the 1970s, archivists only thought about graduate students or professional scholars as archives patrons. By the 1990s, it was common to think of undergraduates in the humanities as appropriate subjects of archival outreach. The small steps into undergraduate STEM courses in recent years may be the beginning of a larger archival trend to come.

Although there has been some effort to bring traditional archival research into STEM classrooms, critical thinking in terms of STEM has often been theorized differently than what one might expect. Douglas, for example, stated overtly that critical thinking is different in the STEM disciplines than it is in the humanities (Douglas, 2012). Felder and Brent (2004) presented a two-part article on educating STEM students that suggests that the main goal of critical thinking in this area is to get students to think on their own. Contrasting critical thinking to the traditional, lecture-based STEM classroom, Felder and Brent hope to inspire students to imagine their own ways of mastering course material, asserting that students who create their own problems, troubleshoot, and predict outcomes learn STEM concepts better.

These goals are admirable, especially based on what some educators report as the failures of their students. Goldberg (2010), for instance, is concerned that his students do not know how to think properly and that engineering curricula are to blame:

> Faculty members defend a "rigorous" curriculum devoted to "the basics" but engineering students have trouble asking questions, naming extant technology or novel technological phenomena, explaining how things work, breaking big problems into solvable little problems, brainstorming and visualizing, and communicating effectively with speech or the written word. (p. 149).

Some educators with concerns like these claim that case studies are the way to bring critical thinking into the STEM classroom because they show students how problem solving takes place in real-world contexts (Yadav, Shaver, & Mecki, 2010). Case studies, it is asserted, also help students to think critically because they must step away from the "oversimplified, theoretical representation of real-world problems" in a lecture classroom and instead learn about the consequences of different approaches to solving problems (Raju & Sankar, 1999, p. 501). Others have suggested how critical thinking is accomplished by having students write about what they are learning (Wheeler & McDonald, 2000). As can be seen, the primary tendency in the literature regarding critical thinking in STEM curricula is aimed at improving student learning of STEM concepts and not directed at their assumptions about STEM itself.

Interestingly, students who may have been exposed to something called critical thinking in STEM may find critical thinking in the humanities classroom an alien experience. Furthermore, if they have engaged in a humanities-style critical thinking project, it may not have been in the context of their STEM education. The STEM approaches to critical thinking are successful tools to improve student learning, but they do not, as we have sought to do, effect awareness about the limitations of a whig approach to history and how this might inhibit efforts to innovate. Critical thinking is, of course, a broad enough concept to allow these approaches and many different ones. Moore (2011) noted the "degree of impatience and frustration" resulting from disputes about the "elusive critical thinking grail" (p. 19). Reporting on a series of interviews, he proposed six "dimensions of difference" that might help advance an understanding of critical thinking (p. 212). What Moore called the objectivist–subjectivist dimension is what is closest to what we have endeavored to inculcate with the archival intervention. He described this dimension as being related to an awareness of how one's methodology for creating concepts and perceiving data might shape the results.

Although Moore has articulated the objectivist–subjectivist dimension in the context of philosophy and literature students, we sought to do something similar for students who are studying engineering. For students identified with STEM, however, there is a challenge to encouraging them to begin this kind of analysis. To a STEM student, thinking about history is something that happens on the other side of Snow's divide. Therefore, initiating critical thinking in a STEM student requires an adjustment of a student's assumption that history is not relevant to innovation. Our project's ability to bring about conceptual changes in STEM students shows its ability to lessen the starkness of Snow's divide. What is more, Moore's tie between the written attitudes of students toward critical thinking, as shown by his surveys, and their readiness to engage in critical thinking, provides an important tie to the present study. Our students' engagement with the archival activity and a written assignment is shown, through pre- and post-experience surveys, to similarly put students in a position for critical thinking.

Methodology

This archival exercise was designed and implemented by an archivist and user services librarian (the "archivist") and a lecturer, advisor, and coordinator of a science and technology studies major ("the instructor") at an engineering school. Although we did not have special support, we were encouraged by both the community of archivists and the culture of invention, innovation, and entrepreneurship (i^2e) that is a hallmark of our school.

1. Overall Setup of the Course

The activity took place in the context of an undergraduate general education course. At the School of Engineering, students are required to take at least four humanities or social science electives after the first-year writing sequence in order to graduate. The course that these students chose to sign up for, Introduction to the History of Western Philosophy, is one they can take among others, such as the Novella, Ethical Questions in Literature, the Natural Environment of New York City, or the History of Light. As seen in Figure 1, there was one Science and Technology Studies major in the class; the remainder of the class showed a distribution of majors, dominated by Mechanical Engineering and Computer Science. Several of the students may have chosen the course because of their interest in history, as it was clear from class conversations that they had some background in US and European history, while others may have chosen the course because it was offered at a convenient time. There were twelve sophomores, eleven juniors, and three seniors enrolled in the course.

Applied Physics	1
Chemical and Biological Engineering	2
Computer Science	8
Computer Engineering	2
Electrical Engineering	2
Mathematics and Physics	1
Mechanical Engineering	9
Science and Technology Studies	1
Total	26

Figure 1. Majors of enrolled students.

The archival activities took place midway through the course. At that point in the syllabus, multiple viewpoints about the same historical period, as well as theoretical articles about the social construction of technology, had been read by the students and discussed in class. One of the primary textbooks for the class, Pursell's (2007) *The Machine in America,* had been partially read, and the instructor had led discussions about how history might be a meaningful part of engineering education. The students had also written and received feedback on one 1,000-word paper regarding the social construction of technology as evinced by class reading assignments. Referring directly to Bruno Latour's (1992) article "Where Are the Missing Masses" and our reading of Myles Jackson's (2000) *Spectrum of Belief,* the assignment asked students to consider how nonhuman actors influence the development of technology. Specifically, students were asked to draw on Latour's theory and Jackson's history to describe the relationship between innovation and the things used to create technology. With the reading assignments, class discussions, and a formal paper in the first seven weeks of class, any critical thinking facility that a traditional course format had inculcated was ready to be measured.

One question we had in preparing this exercise was whether we could provide a vantage point from which students could begin to think critically about the supposed linear paths of history. In order to do this, we surmised, we would have to challenge their notion that history has little to do with the conduct of engineering. The archives assignment was, admittedly, disruptive to the expectations of students and time consuming for the instructor and the archivist. One might expect that students would enjoy the experience, as it takes them out of the classroom and provides them with hands-on activities, but the students' enjoyment of the experience would not necessarily justify the effort expended. From the start, then, we knew that meaningful assessment would be necessary for us to determine whether students initiated a critical attitude toward their preconceptions about history and started on a path to imagining alternatives to the linear path of technological change and innovation.

In order to determine whether the archival intervention made a meaningful impact on students, it was introduced about halfway through the semester, after the midterm exam. Therefore, the students had already been exposed to the instructor's intentions in the course and his ideas about the nonlinear path of technical innovation. By administering the pre-activity survey in the sixth week of class, we wished to imagine what would have happened if we had not made any intervention with the archival activities. The pre-activity survey served as an indicator of what students would have thought about history after completing the course without an archival experience. The results of the follow-up survey, we surmised, would then allow us to see whether students had begun to think critically about how different conceptions of history changed the outcome of historical analysis. The follow-up survey took place in the thirteenth week of class. In the seven weeks between the two surveys, students visited the archives and wrote a paper using archival sources. Even though they continued the classroom activities of the first seven weeks—such as reading secondary material, discussing it in class, taking quizzes, and hearing presentations about the history of technology—the significant change was the archival experience. Thus, any differences between the pre- and post-activity surveys can be attributed to the archival intervention.

2. Archival Activities

Archival instruction in this course was divided into two activities. The first activity was designed as an introduction to archival organization, primary sources, and the various formats that exist within archival collections. A ten-minute introductory lecture covering the basics of the Poly Archives collections and policies, as well as the first archival activity, laid the groundwork for the follow-up activity, which required students to work with selected collections from the Poly Archives and to use these materials as the basis of a 1000–1500-word paper relating to themes from the course.

Our objectives for the first in-class activity[2] were to use tangible examples from the archives to discuss the differences between primary and secondary sources, to get the students to think about different types of primary sources and why they were created (and for whom/what purpose), to think about connections between primary and secondary sources, and to consider how these connections contribute to knowledge production in a scientific discipline. This experience allowed the students to enact connections they had previously only encountered in the course through reading. By using documents from the archives, students were able to physically arrange primary and secondary sources and to make connections between a written definition of a primary source and an actual primary source held in their hands.

In order for us to teach these objectives, the class was divided into five groups. Each group was assigned a different collection of materials to explore. These pre-selected collections from the Poly Archives, all related to science and engineering, included primary sources, such as photographs, notebooks, lab notes, and annotated articles, as well as secondary sources, such as reference books and articles from databases displayed on laptops. We gave the students the names of the collections (for example, the Kenneth S. Wyatt Papers or the Keller Mechanical Engineering Collection), but did not show them the finding aids or any other background information. Their task was to look at these representative materials from a collection and to attempt to make connections between them. Who or what is this collection about? How do the materials relate to each other? What assumptions can be made from this collection or what questions does it raise? The students were given about twenty minutes to look through the materials, to talk to their group members, and to take notes about their findings. This hands-on activity not only exposed the students to the types of materials they would find in the archives, it was also a lesson in proper handling of archival materials: all of the students wore gloves, used only pencils, and understood that some materials may be delicate. Because the students would be returning to the archives to work on individual research papers, it was important for them to understand how to handle archival objects and to be comfortable doing so. One of the initial hurdles in encouraging undergraduates to use archival materials is that the archives, with restricted hours, booked appointments, and a locked door, seem off limits. If we want students to engage in primary source research, it is our responsibility as educators and archivists to teach them how to access and to handle these materials.

The first time the students encountered archival materials, we wanted them to be aware of the diversity of formats that can exist within archives and special collections and also to begin asking questions about these materials immediately. Too often special collections materials are trotted out merely to admire their age or beauty. Although it is nice to appreciate beautiful antiques, this type of showcasing can lead to blindly labeling the object as important without asking more interesting and probing questions about the item's origin and its significance within various contexts. This exercise forced the students to think about reasons why these objects might be significant rather than the archivist telling them why they should be significant. This tactic is similar to inquiry-based learning, an instructional method often used in science courses, to encourage problem solving and decision-making skills (Friedel et al., 2008). Employing an inquiry-based learning model to introduce engineering undergraduates to archival research not only aims to improve critical thinking skills, it is also a learning style which most science and engineering undergraduates will find familiar.

After being given twenty minutes to look through the materials, each group was asked to present its findings to the rest of the class. The students were asked to explain what they found in their collections and what this collection might say about the history of technology. These presentations were bolstered by the instructor, who tied emerging themes back to class readings and previous lectures. Students were sometimes befuddled by what the archival material had to say about their preconceived notions about the history of technology. Even when seeing professors writing letters about funding opportunities from the federal government, for instance, they were unable at first to see how this connected to big science. Furthermore, the extent to which professors seemed to continue their investigations into basic science even in an age supposedly dominated by federal contracts did not seem like an opportunity for them to rethink their assumptions about the uniformity of historical periods until it was pointed out to them. This discussion would set the stage for how the students would approach their own investigations into archival material.

Following this discussion, we wrapped up with a quick quiz on primary and secondary sources. While the archivist held up an item from each collection, students weighed in on clickers[3] as to whether the item was a primary source or a secondary source. Once all of the results were in, we called on students to discuss the reasoning behind their choices. Some items were trickier than others; for example, Samuel Ruben's *Handbook of the Elements*, published in 1965, could be considered a primary source if it were used to inform how scientists thought about elements at that point in history, or it could be used as a secondary source to learn about the elements if the information were still relevant today. Therefore, the clicker "quiz" was not actually about right or wrong answers, but rather was a means to compel all of the students to participate and to illustrate that multiple answers could be correct depending on the supporting explanation.

At the end of this class, students also used their clickers to select which archival collection they would like to explore during the next archival activity. The choices included the five collections we previewed during the introductory activity as well as three additional collections. Because we were near the end of the class period, we could only provide very brief descriptions of the collections, and the students had to choose quickly. These eight groups were then divided in half; the first four groups would work in the library the following week and the second four groups would visit the library in two weeks.

The second, and final, archival activity, which brought the students to the library, allowed for a closer inspection of their selected collections and required them to write a paper using archival sources. This library visit began with stowing coats, bags, and coffee mugs in a staff area behind the circulation desk. The students then visited the archives to get a sense of where their collections were typically stored and to discuss what types of collections were held in the space. The visit to the archives also made it clear why the entire group would not be working in that room. Our library lacks a special collections reading room, and the tables in the archives can comfortably support only one or two researchers at a time. To accommodate this larger group of researchers, the archivist set up four tables—one for each collection—in a staff area adjacent to where the students stored their belongings. In an attempt to maximize space, the archivist added to each table a book cart to hold the collection's boxes. While this setup was still a bit cramped, it was workable.

Although students are familiar with the productive spaces of technical inquiry from their required laboratory courses, this for many of them was the first time they had encountered a working space for the humanities, where hypotheses about history are challenged, contradicted, and revised.

Each group was provided with a print-out of the Scope and Contents and Biographical/Historical notes from its collection's finding aid. A laptop with the full finding aids was also available to the students. The archivist advised students to record information about the collection while taking notes (i.e., collection name and number, box number, folder number, and the title, date, and creator of the item) and distributed a handout, which explained how to cite archival sources in MLA and APA formats.

Although each student would ultimately write an individual paper, the students were able to work in groups while they examined their collection. The archivist was also on hand to answer any questions or to ask additional prompts that might aid the students' research. The students had the full class period (110 minutes) to look through the collections and were invited to stay later if they needed more time. With two weeks between the in-class research and the paper due date, the students also had time to visit the archives again if needed.

Each group also received a set of three research prompts[4] created by the archivist. The students were free to use one of these prompts as the basis for a 1000–1500-word research paper or to pick their own research focus. The instructor, thus, set minimal guidelines for the creation of the paper. The most specific requirements were that the paper needed to relate to themes from the course readings and discussions, and it had to be grounded in archival materials. The instructor encouraged the students to think about classroom discussions about innovation and entrepreneurship, hopefully using ideas about the social construction of technology to discuss "pitfalls and opportunities" of invention, innovation, and entrepreneurship. Students had the opportunity to meet with the instructor or the archivist for more discussion while they were working on the paper, although as one might expect, not all students availed themselves of this opportunity.

3. Assessment

In order to assess the impact of the archival activities, we distributed surveys before and after the students' work with archival primary sources. Both surveys were voluntary and anonymous. Because the surveys were distributed during a class period and were voluntary, we do not have an equal number of respondents to the pre and post surveys (26 students completed a pre-activity survey; 24 completed a post-activity survey). Also, due to the anonymity of the surveys, we could not track individual student gains between the pre and post surveys, nor was this our goal. Our purpose was to get an overall sense of shifts in perception across the class because a broader idea of the contingency of history and the influence of interpretive frameworks on the results of history would demonstrate that we had helped them to begin thinking critically. Given that students were only exposed to archival materials during two in-class activities, we did not expect to see dramatic changes; however, we did observe from their answers before and after the archival activities meaningful evidence of a shift in perception that readies them for critical thinking.

The surveys consisted of both quantitative and qualitative questions. The first five qualitative questions (Figure 2) were the same on both surveys. In the pre-activity survey, these five questions were followed by two questions (Figure 3). In the post-activity survey, the first five questions were followed by four questions (Figure 4).

1.) Is there a difference between an archive and a library? If so, what is it?
2.) What is a primary source? Please provide a few examples from this class.
3.) Why do historians use primary or archival sources?
4.) What are some challenges with using primary sources?
5.) How can primary sources improve our understanding of invention, innovation, and/or entrepreneurship?

Figure 2. Survey questions asked before and after activity.

6.) Have you ever worked with archival material before? If Yes, what material have you worked with?
7.) How confident are you that you could do research with primary sources?
1 (not at all confident) 2 3 4 5 (extremely confident)

Figure 3. Survey questions asked only before activity.

6.) What did you like best about working with archival material?
7.) What did you like least about working with archival material?
8.) What was missing from this introduction to archival materials that could have helped you?
9.) How confident are you that you could do research with primary sources in the future?
1 (not at all confident) 2 3 4 5 (extremely confident)

Figure 4. Survey questions asked only after activity.

By asking the same five questions before and after the archival activities, we hoped to evaluate changes in the students' understanding of archival collections, primary sources, and the relationship between primary source research and innovation, invention, and entrepreneurship. Question 5 was of particular interest to us, as we would use it to ascertain how well readings and discussions about social constructivism, and later, research with archival collections, impacted students' attitude toward history's place in an engineer's education. Questions 6 and 7 in the pre-activity survey gave us a bit of baseline information about the students' previous exposure to archival materials and their level of comfort working with primary sources. On the post-activity survey, Questions 6 through 8 were designed to give us some feedback about what might have been lacking or frustrating about the archival instruction portion of the course. We hoped these questions would help us to improve the course design and that they may be helpful for others considering a similar project. Question 9 allowed for a quantitative comparison to Question 7 in the pre-activity survey.

It was important to us to include qualitative questions in the survey. These written responses allowed the students to more fully express what they had learned and allowed us to see changes in their perspectives that would indicate a readiness to begin critical thinking regarding the connections between history and STEM disciplines. In order to see the extent to which the class was ready for critical thinking, we collaboratively developed a rubric to separate what we thought were naive answers about archives and history in general from more nuanced answers that we would expect to come from studying in the course. We went through multiple versions of the rubric until we reached an agreement regarding the categories and the scores. The pre-activity survey demonstrated the extent to which some students had already gotten the point without the archival activity, and the post-activity survey reflected what had changed based on students' exposure to the archival research.

Results and Discussion

Almost half of the students (42%) reported that they worked with archival materials before taking this course, compared to 27% of the students who had never worked with archival materials (Figure 5). It is interesting to note that 31% of the students responded "don't know" as to whether they had worked with archival materials before.

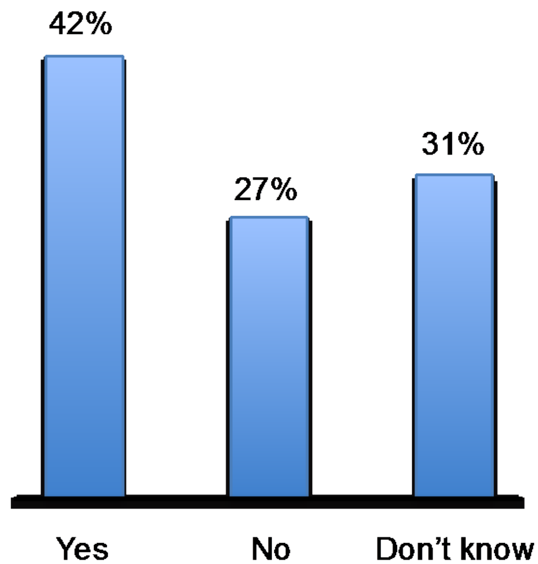

Figure 5. Have you ever worked with archival material before?

After visiting the Poly Archives and working with archival materials, students were more likely to identify key differences between a library and an archive. In the initial survey, 23% of the students were able to identify two or more features that distinguished archives from libraries; after the archival activities, 41% of students identified two or more features.

The biggest change in these responses was the understanding that archives contain original and primary source materials. In the pre-activity survey, 8 out of 26 respondents (30%) mentioned primary or original sources as a part of archives, while in the post-activity survey 14 out of 24 respondents (58%) mentioned primary or original sources as part of archives. Besides this, the responses showed an uptick in the use of specialized terminology. In the pre-activity question, students were more likely to indicate that sources in the archives were original, whereas in the post survey students specifically used the term "primary sources."

Figure 6 shows the six categories we used to score each answer to Question 1, as well as sample responses from various students. We wanted to account for not only what the students said, but also the complexity of their answers. For example, if a student mentioned that archives contained primary sources, noted various format types, and wrote that these collections are curated around a particular focus, we scored the student as giving three informed answers to represent each of the three categories mentioned.

Alternatively, if the student left the question blank or gave a surface or incorrect response, we scored that answer as having no informed answers. After working with archival materials in this course, students were more likely to move along the gradient from incorrect answers to more complex, informed answers (Figure 7).

Category	***Sample response***
N/A	Blank
Surface details/Incorrect	"Archives are more strict on verifying the source"
Historic material	"A library is a place to read and borrow books and other medias [*sic*]. An archive is a place of information of the past in the form of books, articles, etc."
Primary sources	"An archive has primary sources while a library has secondary and higher. An archive would have articles, correspondence, and more from the time by the author."
Various formats	"An archive has a larger range varying from books to articles to newspapers. A library on the other hand might not have all these resources. It might be common to find books but not newspapers."
Focus/Curated	"Yes. While a library would be a massive collection of information, an archive would be a more controlled source of information on a particular subject."

Figure 6. Is there a difference between a library and an archive?

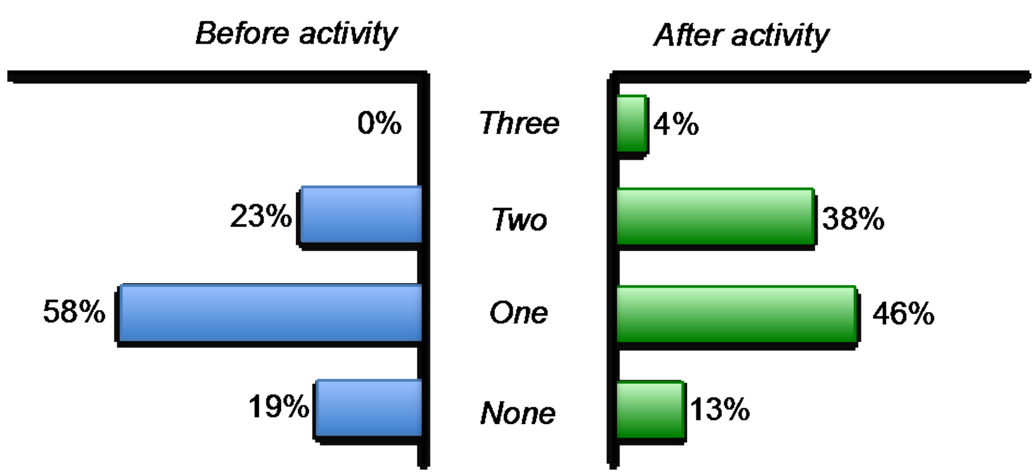

Figure 7. Percentage of informed answers to Question 1 (What is the difference between a library and an archive?).

Many students (80%) knew what a primary source was before the introduction to archival activities in this class. Although they could correctly define a primary source, very few were able to give examples of primary sources from first-hand experience. When asked for an example of a primary source, most of the students referenced a primary source they had read about in a secondary source. After the course, significantly more students were able to give more than one example of a primary source (4% pre; 50% post), and those examples were more likely to be primary sources with which they had hands-on experience (Figure

8). For example, in the pre-activity survey, many students mentioned Fraunhofer's journal, which was referenced in a class reading (Jackson, 2000), as a primary source. After the archival activities, students were more likely to cite a primary source with which they had direct contact, such as the Leonard Shaw Papers or the Keller Mechanical Engineering Collection.

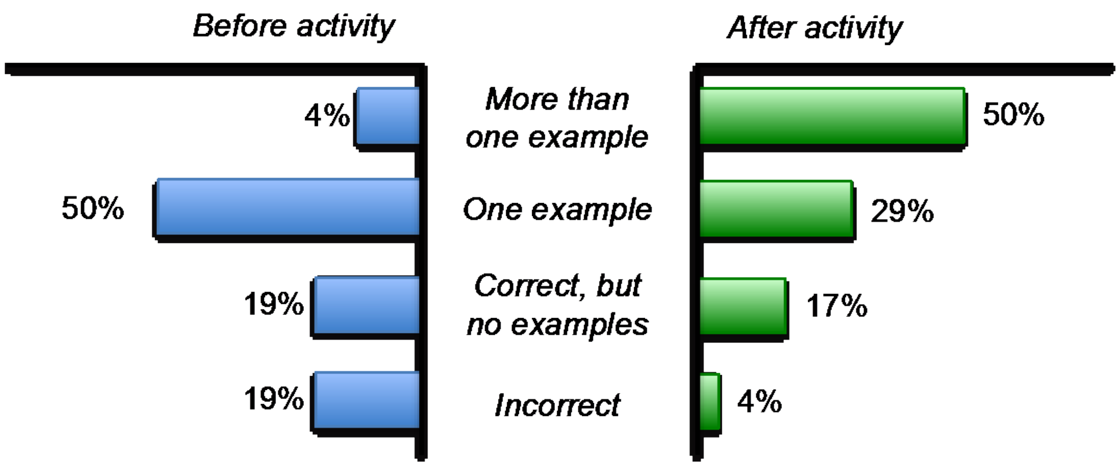

Figure 8. Percentage of informed answers to Question 2 (What is a primary source?).

Before working with primary sources, 42% of students said that historians use primary sources because they are "true" or "unbiased accounts." After working with archival materials, this kind of surface answer dropped to 29% and students were more likely to indicate that historians use primary sources in order to gain insight into the subject's thought process or to better understand a point of view. While only 3 out of 26 (11.5%) of students included this idea in their answers before working with primary sources, in the post-activity survey the number rose to 9 out of 24 (37.5%).

Category	***Response example***
N/A	Blank
True, unbiased	"Historians use primary or archival sources because they are not biased and are original."
Insight into history	"Historians use primary or archival sources because it provides a deeper view of a subject compared to one such as a newspaper article."
Insight into people's thinking/point of view	"They provide insight into the minds of individuals at the time, a subjective framework on which a historical analysis can be made."
Create original assessment rather than relying on a secondary source	"So they can see historical documents for themselves and make analysis of it instead of analysis of someone else's analysis."

Figure 9. Why do historians use primary sources?

We scored the answers to Question 3 in the same way we scored the answers to Question 1. This time we were looking for answers that moved away from stating that a primary source is simply "true" to talking about point of view, insight into thought processes, and the ability to create an original analysis rather than to rely on a secondary source (Figure 9). Figure 10 compares the percentages of students giving an incorrect response ("None"), one correct response, and two correct responses, before and after the archival activities.

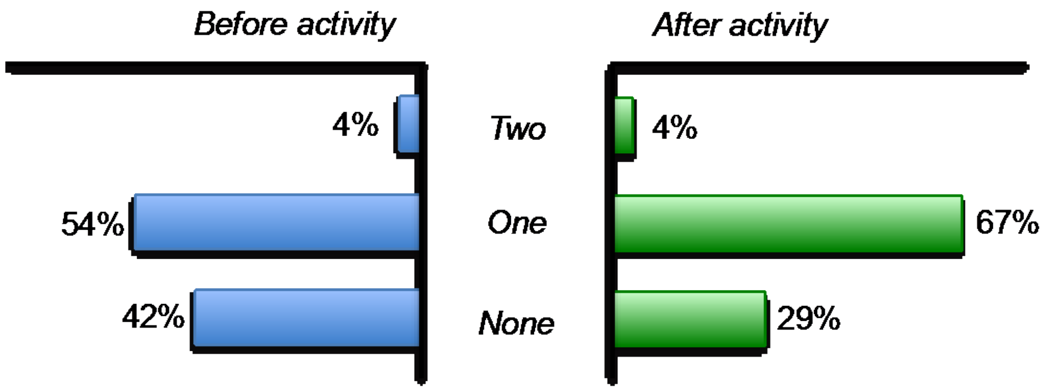

Figure 10. Percentage of informed answers to Question 3 (Why do historians use primary sources?).

The students had a range of responses to Question 4, which asked them to identify the challenges of working with primary sources. Based on their answers, we scored the question on seven categories: no response or an answer of "I don't know," gaining access to archival collections, destruction or fragility of archival materials, trusting the creator of the material or understanding bias, linguistic or cultural barriers, creating an original interpretation of the materials, and archival silences. In Figure 11, "None" represents students who either gave no response or said "I don't know." All of the other responses were scored as informed responses.

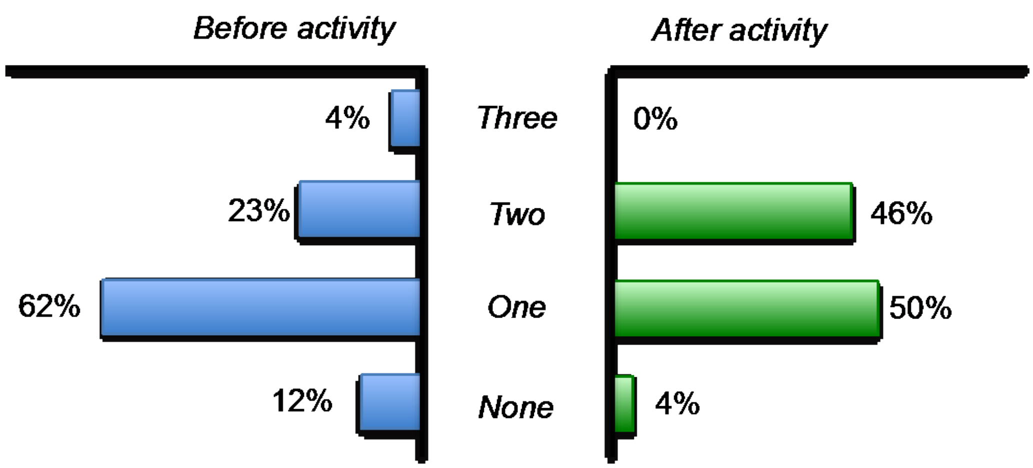

Figure 11. Percentage of informed answers to Question 4 (What are some challenges with using primary sources?).

Before the students worked with materials from the archives, they were more likely to indicate that they did not know the challenges of working with primary sources or that they imagined access to these materials would be the most significant challenge (34% pre; 8% post). After the two archival activities, not only were they less concerned about how to access archival materials, their ideas about the challenges of working with primary sources became more complicated, with 50% replying that making their own interpretations from the materials was the most challenging aspect, compared to only 11% who identified this challenge in the pre-activity survey. The students also gained new terminology to express some of the challenges associated with archival collections. In the post-activity survey, 3 students specified "archival silences" as a challenge, whereas in the first survey none of the students used that term.

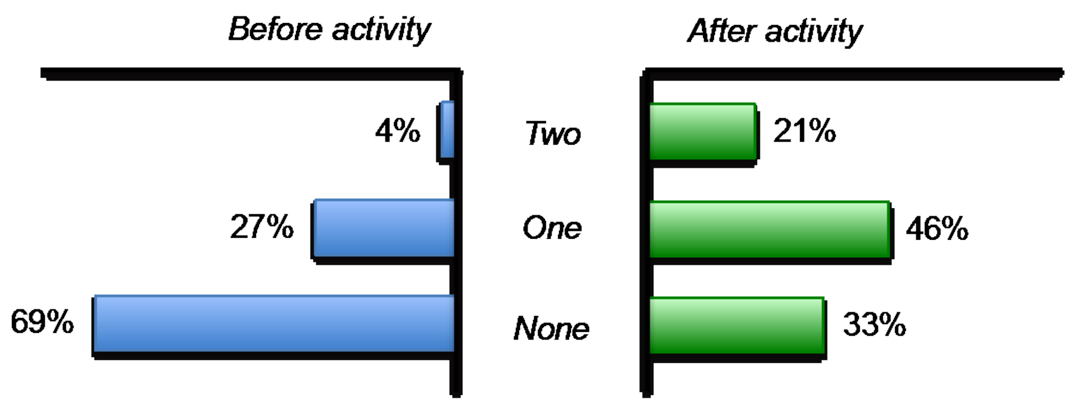

Figure 12. Percentage of informed answers to Question 5 (How do archives improve understanding of i^2e?).

Category	***Response example***
N/A	Blank
Surface understanding/"True facts"	"From looking at primary sources we can see the actual facts of a certain event and can learn what has actually happened. If we use secondary sources, facts can be skewed to fit one argument or another."
Interaction between society and inventor/invention	"They will give us an insight into the mindset and perception of time-period, thus allowing us to understand both the how and the why an invention turned out the way it did."
Inspire/influence new inventions	"We can see what kinds of challenges others have faced and learn from them. We can understand better how the present differs from the past and adapt."
The process of invention: how innovators work and think	"They provide us with insight to the way innovators and inventors work and think, which can help us understand their creative process."
Understanding challenges to inventing	"They reveal some challenges that we never would have imagined."

Figure 13. How do archives improve understanding of i^2e?

Before working with collections from the Poly Archives, most of the class (69%) could not sufficiently answer the question about how archives could improve understanding of i^2e (Figure 12). After working with archival materials, this percentage dropped to 33%, and students were more likely to apply STS concepts to understanding invention, innovation, and entrepreneurship. We scored responses to this question in the same manner as we scored

Questions 1 through 3 (Figure 13). After the archival activities, students were more likely to consider challenges or conflicts to invention (0% pre; 21% post) and were more likely to think about the inventor's thought process or the process of invention rather than the results (11% pre; 37% post).

Question 7 on the pre-activity survey and Question 9 on the post-activity survey asked the students to indicate their confidence level of conducting research with archives materials using a five-point Likert scale (Figure 14).

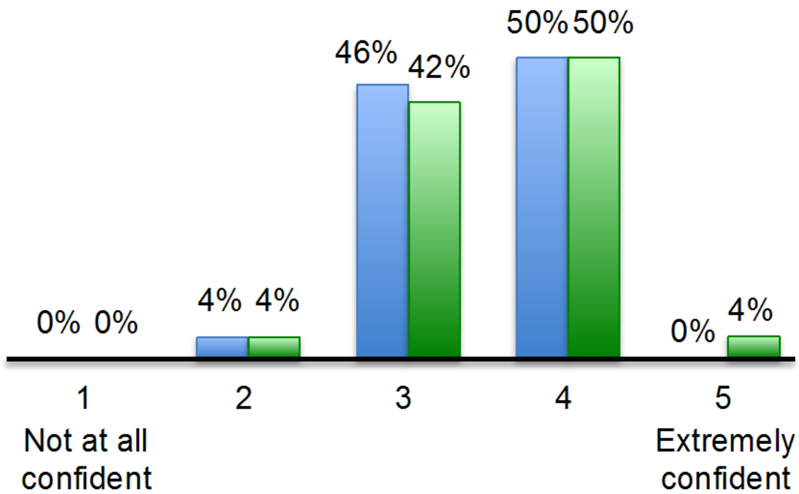

Figure 14. How confident are you that you could do research with primary sources (blue) / in the future (green)?

Although Questions 1–5 indicate that students are thinking more critically about archival research, this short exposure to archival materials did not impact the students' confidence in conducting archival research. It is interesting to note that in the post-activity survey, three students wrote in 3.5, which was not an option on the Likert scale. It is possible that this represents a modest self-perceived gain (or loss) in confidence working with archival materials. More interesting to note is that the qualitative questions, though more time-consuming to score, revealed gains in understanding archival research and its relationship to i^{2}e; however, this quantitative question failed to show much change at all. The students' self-perceived proficiency at a skill may not be the same as their successful understanding of the skill.

Post-activity survey Questions 6 to 8 asked the students to provide us with a qualitative evaluation of the archival activities. There is an interesting overlap in responses between Question 6, "What did you like best about working with archival material?" (Figure 15), and Question 7, "What did you like least about working with archival material?" (Figure 16).

Some students reveled in the freedom to draw connections and to formulate an argument based on archival evidence; in the context of critical thinking, they were impressed by the opportunity to imagine the consequences of different hypotheses. Conversely, some students were frustrated by the lack of secondary source materials to guide them, and they found the open-ended nature of archival research to be the most challenging, and least pleasant, aspect of this exercise. It is possible that these students were ones who had no previous experience working with archival material and could have benefitted from a more in-depth description of the finding aid, the collection, and how to begin searches for secondary sources in library catalogs and databases; however, we might also suspect that those students were comfortable with a version of history that does not require them to think of it as constructed. At the same time, some of these answers reveal that students used critical thinking to reach a deeper understanding of archival collections than a novice researcher would possess. The three students who specifically cited "archival silences" as a frustration have an awareness of archival terminology and identified a problem that can frustrate seasoned researchers.

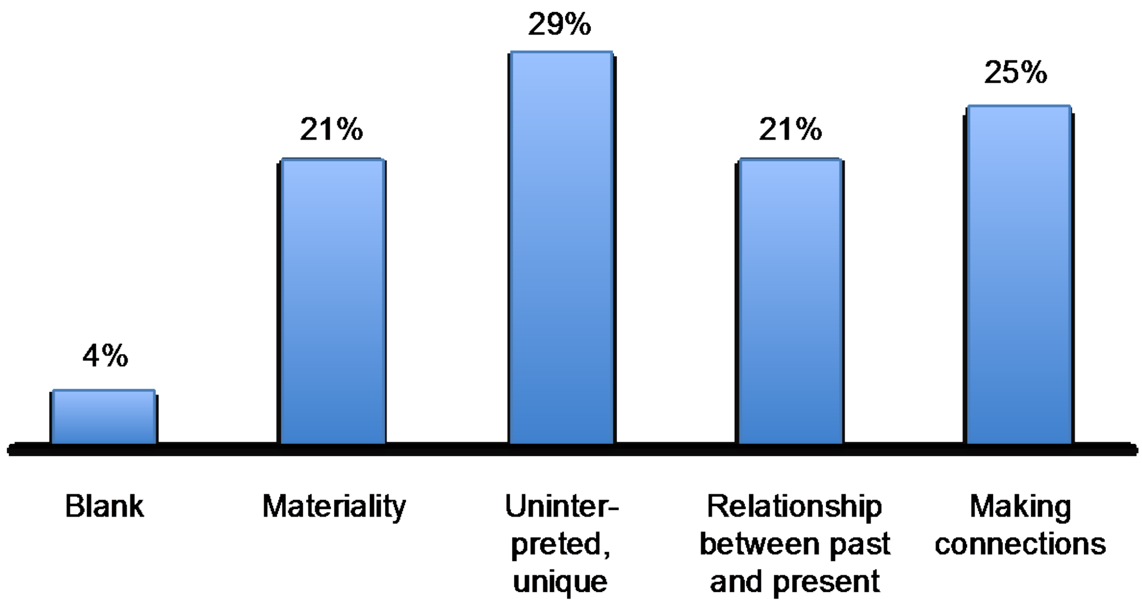

Figure 15. What did you like best about working with archival material?

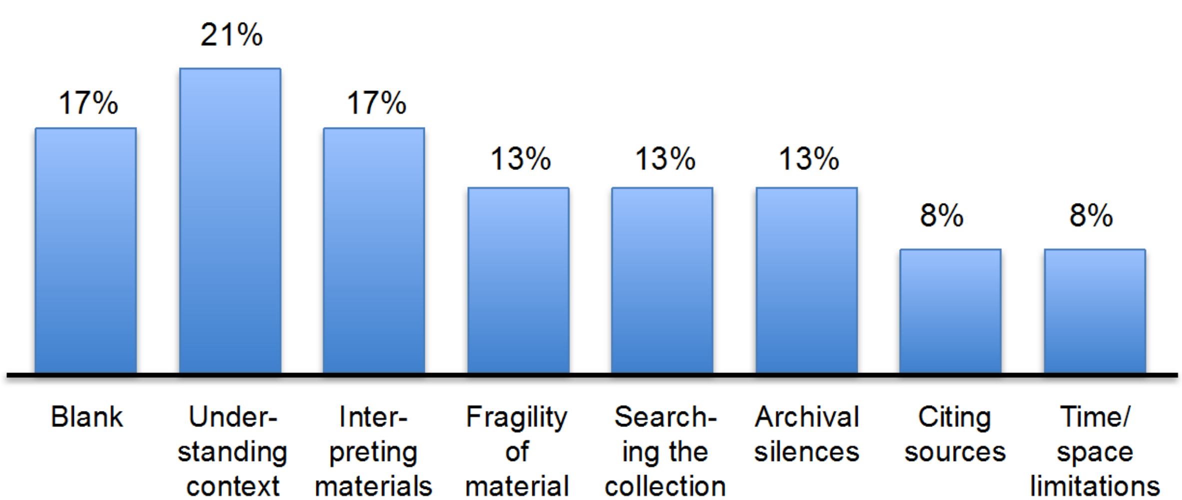

Figure 16. What did you like least about working with archival material?

Because many students found searching the collection, interpreting archival materials, and understanding context their least favorite parts of working with archival material, it follows that 38% of the students responded to Question 8 (Figure 17) indicating that they would like either more context or more guidance. These responses are tempered by 29% of the students responding that nothing was missing from the introduction to archives and the 25% who left this question blank. The discrepancies in these responses could indicate a range of prior experience, ability, and engagement across the class.

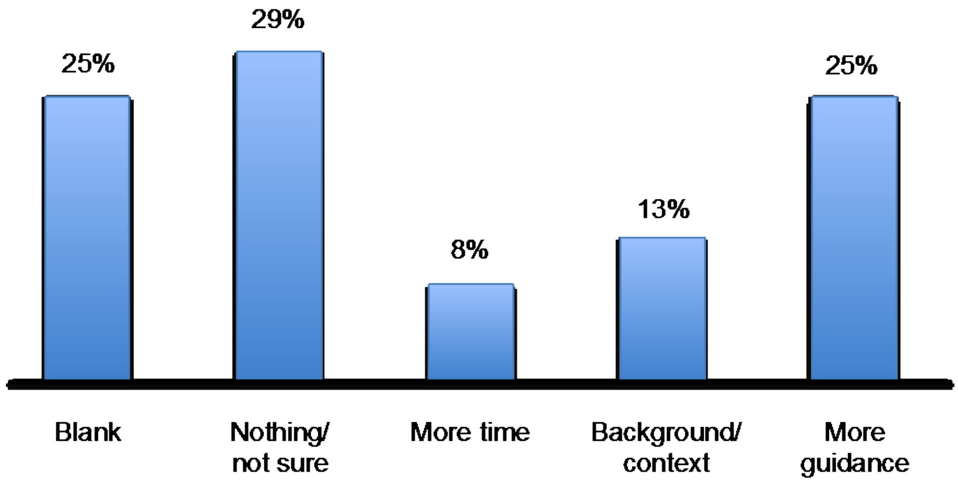

Figure 17. What was missing from this introduction to archival materials that could have helped you?

We were particularly interested in one student's response to the question of what he or she liked best about working with archival material: "It was a window into another world into which I'd sometimes imagined myself, but never came into such close contact." This student's experience transcends an understanding of why we use primary source materials in research and gets to an interesting point about what it means for STEM students to encounter the archival collections of former working scientists and engineers. Slogging through difficult mathematics and science courses is an accepted reality of the STEM undergraduate degree, but all of that conceptual groundwork can distance students from the actual work of their future careers. For this student, the work in the archives brought the world of real scientists closer and provided a connection to his or her future field.

Conclusion

Ameliorating "dangerous" divides—be they between the humanities and social sciences or between staff and faculty—has proven possible in this exercise. Productive partnerships can be formed between librarians and course instructors, even without large budgets, to form effective classroom experiences for students. Although our library lacks a special collections reading room, and our archives are not as expansive as many university collections, we were able to use our extant space and collections in order to provide meaningful engagement in primary source material. In fact, using the collections in this way has particular benefits for utilizing small collections, which may be overlooked by outside researchers. While these may not be our big ticket items, they were valuable for teaching STEM students about the connections between the primary source documents of scientists and innovation in a particular discipline. The students' written responses to the post-activity survey show that working with archival materials encouraged them to begin to think critically about the role of innovation in STEM disciplines.

It is important for the archivist and the instructor to consider potential challenges involved in this type of project. The archivist and the instructor must be willing to take on the time commitment of planning the course, selecting appropriate collections, devising assessments, and creating supplemental hand-outs, such as research prompts and instructions for citing archival sources. For the instructor, this means taking the time to understand the archival collections at the university and how these could relate to a particular course. For the archivist, it means being available to provide instruction during the instructor's class periods.

The biggest challenge for the archivist in this project was figuring out how to assist a large group of patrons working on multiple research projects, rather than working with an individual researcher. In a typical research appointment, the archivist is able to tailor advice to the researcher's ability and interests. Novice researchers may need extra help with reading a finding aid or knowing where to find additional related materials, while seasoned researchers may find attempts to overly instruct them redundant and annoying. In a class of mixed experience and abilities, it can be difficult to calibrate this level of instruction. One way around this may be to provide supplemental hand-outs or libguides. The class will not be bogged down with additional lectures that may be unnecessary for some students, while students who need more help, but may be reluctant to ask, will have the resource on hand.

While there is room for improvement as we continue archival activities with STEM undergraduates, we were pleased to see gains achieved through this modest introduction. At the end of the course, students had a better understanding of archives, primary sources, and how these resources can contribute to understanding i^2e. We are particularly encouraged by student comments about how this archival experience gave them contact with the profession. One common complaint given by students who are thinking about leaving STEM is that their introductory coursework in the first two years of college does not connect with their career ambitions. Thus, the i^2e experience provided to students via this archival exercise may be a way to satisfy these students before the junior year, and so may help with retention efforts while satisfying general education requirements.

As we look to the future, we should also consider incorporating history of technology archival experiences into the curriculum for history majors. To truly address Snow's dangerous divides, the work must go in both directions—outreach from the humanities to inform scientists of history and outreach from science collections to inform historians of our technological past. Our experience provides a practical example of how to cross the divide, not only between history and science, but also between two cultures of the university: the academic departments and the library.

Notes

[1]Until 2008, the school was known as Polytechnic University. At that time, the school began a merger with NYU and an interim organization was formed known as the Polytechnic Institute of NYU. In 2014, with the merger completed and the school becoming one of NYU's institutes, the name NYU Polytechnic School of Engineering was used. Recently, in gratitude for a generous donation, we have taken the name NYU Tandon School of Engineering.

[2]See Appendix A for the archival activity lesson plan.

[3]Classroom clickers, or student response systems, are wireless handheld devices that enable students to respond to questions and to project the aggregate class response on the board. Grateful acknowledgement is given to training and equipment provided by the Center for Faculty Innovations in Teaching and Learning at NYU Tandon.

[4]See Appendix B for research prompts created by the archivist.

References

Anderberg, L. (in press). STEM undergraduates and archival instruction: A case study at NYU Polytechnic School of Engineering. *The American Archivist.*

Bijker, W. E. (1992). The social construction of fluorescent lighting, or how an artifact was invented in its diffusion stage. In W. E. Bijker & J. Law (Eds.), *Shaping technology/ building society: Studies in sociotechnical change* (pp. 75–102). Cambridge, MA: MIT Press.

Bowker, G. (1992). What's in a patent? In W. E. Bijker & J. Law (Eds.), *Shaping technology/ building society: Studies in sociotechnical change* (pp. 53–74). Cambridge, MA: MIT Press.

Brown, A. H., Losoff, B., & Hollis, D. R. (2014). Science instruction through the visual arts in special collections. *Portal: Libraries and the Academy, 14*(2), 197–216. doi:10.1353/ pla.2014.0002

Bunde, J., & Engel, D. (2010). Computing in the humanities: An interdisciplinary partnership in undergraduate education. *Journal of Archival Organization, 8*(2), 149–159.

Carini, P. (2007). Archivists as educators: Integrating primary sources into the curriculum. *Journal of Archival Organization, 7*(1–2), 41–50.

Douglas, E. P. (2012). Defining and measuring critical thinking in engineering. *Procedia - Social and Behavioral Sciences, 56,* 153–159. Retrieved from http://doi.org/10.1016/ j.sbspro.2012.09.642

Felder, R. M., Brent, R. (2004). The intellectual development of science and engineering students. *Journal of Engineering Education, 93*(4), 269–277, 279–291.

Friedel, C., Irani, T., Rudd, R., Gallo, M., Eckhardt, E., & Ricketts, J. (2008). Overtly teaching critical thinking and inquiry-based learning: A comparison of two undergraduate biotechnology classes. *Journal of Agricultural Education, 49*(1), 72–84.

Haynes, C., & Leonard, J. B. (2010). From surprise parties to mapmaking: Undergraduate journeys toward interdisciplinary understanding. *The Journal of Higher Education, 81*(5), 645–666.

Jackson, M. W. (2000). *Spectrum of belief: Joseph von Fraunhofer and the craft of precision optics.* Cambridge, MA: MIT Press.

Johnson, G. (2006). Introducing undergraduate students to archives and special collections. *College & Undergraduate Libraries, 13*(2), 91–100. doi:10.1300/J106v13n02•07

Latuor, B. (1992). Where are the missing masses? The sociology of a few mundane artifacts. In W. E. Bijker & J. Law (Eds.), *Shaping technology/building society: Studies in sociotechnical change* (pp. 225–258). Cambridge, MA: MIT Press.

Krause, M. G. (2008). Learning in the archives : A report on instructional practices. *Journal of Archival Organization, 6*(4), 233–268.

Mazak, J., & Manista, F. (1999). Collaborative learning : University archives and freshman composition. *Reference Librarian, 32*(67–68), 225–242.

Mitchell, E., Seiden, P., & Taraba, S. (Eds.). (2012). *Past or portal?: Enhancing undergraduate learning through special collections and archives*. Chicago, IL: Association of College and Research Libraries, a division of the American Library Association.

Moore, T. J. (2011). *Critical thinking and language: The challenge of generic skills and disciplinary discourse.* New York, NY: Continuum.

Pacey, A. (1991). *Technology in world civilization: A thousand-year history.* Cambridge, MA: MIT Press.

Pederson, A. E. (1978). Archival Outreach: SAA's 1976 survey. *The American Archivist, 41*(2), 155–162.

Pinch, T. (2005). Giving birth to new users: How the Minimoog was sold to rock and roll. In N. Oudshoorn & T. Pinch (Eds.), *How users matter: The Co-construction of users and technology* (pp. 247–270). Cambridge, MA: MIT Press.

Pursell, C. W. (2007). *The machine in America: A social history of technology.* Baltimore, MD: Johns Hopkins University Press.

Raju, P. K., & Sankar, C. S. (1999). Teaching real-world issues through case studies. *Journal of Engineering Education, 88*(4), 501–508.

Shapin, S., & Schaffer, S. (2011). *Leviathan and the air-pump: Hobbes, Boyle, and the experimental life.* Princeton, NJ: Princeton University Press.

Snow, C. P. (1959). *The two cultures and the scientific revolution*. New York, NY: Cambridge University Press.

Society of American Archivists. (2015). Core archival functions | Society of American Archivists. Retrieved from http://www2.archivists.org/node/14804

Vanasupa, L., Stolk, J., & Herter, R. (2009). The four-domain development diagram: A guide for holistic design of effective learning experiences for the twenty-first century engineer. *Journal of Engineering Education, 98*(1), 67–81.

Wheeler, E., & McDonald, R. L. (2000). Writing in engineering courses. *Journal of Engineering Education, 89*(4), 481–486.

Yadav, A., Shaver, G. M., & Mecki, P. (2010). Lessons learned: Implementing the case teaching method in a mechanical engineering course. *Journal of Engineering Education, 99*(1), 55–69.

Appendix A

Archival Intro Activity for HI 2234
November 4, 2014 | 110 minutes

Objectives:
1.) To discuss the differences between primary and secondary sources through hands-on experience with archival materials.

2.) To understand how primary and secondary sources contribute to knowledge production in scientific fields.

3.) To think about different types of formats and the means of their creation. When, how, for what purpose/for whom, where were these documents created.

4.) To gain a preliminary understanding of the types of items archives collect and how they can be used for research.

Class outline:
1.) Introduction and description of the Poly Archives (http://library.poly.edu/archives). Ascertaining what level of experience the students have with archival materials. A short explanation of archival practice and terminology: finding aid, provenance, primary sources and secondary sources (http://guides.nyu.edu/content.php?pid=632933&sid=5237162) (**10 minutes**).

2.) Ask the students to pick a collection of materials to explore (5 groups of 5). The students will be asked to explore the groups of materials and to think about why/when/how/for whom the materials were created and to think about how all of these objects are connected and what was happening during this time period in the history of technology. I will walk around the room during this exploration and talk to the students about what they're finding. (**15-20 minutes**).

3.) Each group will present their findings to the class. (**10 minutes/group**).

4.) As a class, we will pick a few items and discuss whether we these are primary or secondary sources. This can be a clicker activity—click primary/secondary, then discuss (**15 minutes**)

5.) After each group has presented/discussed, we can have a broader discussion about how these objects tie into the history of technology. What do they say about the production of knowledge? Would seeing an object out of context change or confirm your ideas about the history of technology? How would you go about interpreting a primary source document that doesn't have supporting information? (**20 minutes**)

6.) A brief introduction of other archival collections that could be used for next class. Explain next week's archival activity and allow the students to select which materials they'd like to work with next week. The materials they select will determine which day they visit the archives (4 sets 11/11 and 4 sets 11/13) (**5 minutes**).

Appendix B

Archival Collections for Exploration
November 11 and 13, 2014

Review the collections from the Poly Archives & Special Collections below and select one you would like to explore. Each collection includes either a Scope and Contents note or a Biographical/Historical Note pulled from the collection's finding aid. These notes will give you an overview of the subject matter and types of materials in the collection. Follow the link to the finding aid for more detailed information about the collection. The research questions associated with each collection will help to guide and frame your thinking as you explore the collection and begin to write your essay.

1.) Keller Mechanical Engineering Corporation Collection (RG.001)

http://dlib.nyu.edu/findingaids/html/poly/keller/

Scope and Contents note

The Keller Mechanical Engineering Corporation Collection includes company records, operating manuals, notebooks, scrapbooks, photographs, sketches, blueprints, publications, advertisements, newspaper clippings, ephemera, and product samples from 1916 to 1962. Due to preservation concerns, some materials were removed from their original housing. This is noted in the finding aid and, when possible, notebook and photo album covers were encapsulated and separated, but retained in the collection. If photographs were removed from an album or scrapbook, the original layout of the photographs is noted.

This collection documents machines and products of the Keller Mechanical Engineering Corporation (KME) during its peak production years. Through the engineering innovations of the Sydney and Joseph Keller and their partner, John C. Shaw, the company, which began as an engraving shop in the late 19th century, grew to become an integral part of the twentieth century manufacturing industry. As KME produced newer, faster, and larger tool and die machines, the product line expanded from silverware to granite facades to automobile and aircraft parts. As KME's reputation grew, Keller machines were sold to factories in Philadelphia, Upstate New York, Detroit, and England. Mirroring the trajectory of many early twentieth century factories on the Brooklyn waterfront, KME eventually moved to a larger plant in Connecticut and merged with the Pratt & Whitney Company.

Research Questions:

1.) How does the Keller Mechanical Engineering Corporation Collection inform your understanding of machines and mechanical production in 20^{th} century America?

2.) Do the primary source documents in this collection show evidence of a shift in technology over time?

3.) Are there holes in the collection (archival silences) that could impact the way you interpret this collection? Is there information you wish was included in the collection?

2.) Samuel Ruben Papers (RG.015)

http://dlib.nyu.edu/findingaids/html/poly/ruben/

Biographical / Historical note

Samuel Ruben was born on 14 July 1900 in Harrison, New Jersey. He was an American inventor who made lasting contributions to the fields of electrochemistry and solid-state technology. While he dropped out of college and had no formal education, his scientific career spanned over 60 years. Ruben produced over 300 patents, many of which were developed at Ruben Laboratories in New Rochelle, which he founded. Ruben held honorary degrees from Polytechnic Institute of New York (where he was also an honorary Professor), Butler University, and Columbia University.

In the 1920's, Ruben's dry electrolytic capacitors made possible the first low-cost plug-in radios with greater durability, significantly longer shelf life, and longer operating lifetime. Ruben's improvement to the AC Vacuum Tube shortened the warm-up time and extended the lifetime of the product. This technology was used in the Boulder Dam generators, among others. The Photolytic Cell was capable of noise-free response to audio frequencies. The Ruben Vacuum Tube Relay responded to audio and radio frequencies and found application in various remote-controlled devices, such as railway signal systems, telephone relay circuits, and general call systems. Other inventions include the Glass Mesh Fluorescent Tube, a portable gamma detector, and a device that was commercially applied to phonographs which created an improved low frequency response.

The licensee of many of his inventions was P.R. Mallory Company, which later became Duracell. Ruben and Philip Rogers Mallory invented the mercury button cell in 1942 in response to an urgent need created during World War II for a miniature battery that would not deteriorate in tropical climates and would be capable of maintaining voltage on loads and retaining transmission range. The sealed alkaline cell made possible the miniature batteries used in implanted cardiac pacemakers, hearing aids, watches, cameras, transistor radios and other electronic devices. He died on 16 July 1988 in Oregon.

Research Questions:

1.) What can a collection of one scientist's patents tell us about a specific era of technology development?

2.) How do primary source materials in the Ruben collection enhance or complicate your understanding of the development of technology in the twentieth century?

3.) Are there holes in the collection (archival silences) that could impact the way you interpret this collection? Is there information you wish was included in the collection?

3.) Leonard Shaw Papers (RG.008)

http://dlib.nyu.edu/findingaids/html/poly/shaw/

Biographical / Historical note

Professor Leonard Shaw joined the faculty at Polytechnic University in 1960, where he taught Electrical Engineering (EE) for 43 years. During that time, Shaw also served as the Head of the Department of Electrical Engineering and Computer Science from 1982- 1990, and then Dean of the School of EE and CS until 1994.

Scope and Contents note

The Leonard Shaw Papers includes departmental records, memorandum, and correspondence concerning the Electrical Engineering and Computer Science Department from 1973 through 1999.

This collection documents the merger with NYU in 1973 and some of the effects on the EE/CS Department and students, primarily in regards to confusion surrounding graduation requirements. This collection also contains records from the departmental decision to eventually phase-out the evening course offerings for the BS in EE program in 1989. Also included in the collection are records of the planning, implementation, and assessment of joint EE degree programs offered in cooperation with both Reiss-Romoli in Italy in the early 1990s and the School of Television and Cinema in Tehran, Iran in the late 1970s. Lastly, the collection contains records of the National Science Foundation Graduate Research Traineeship from 1993 through 1999.

Research Questions:

1.) How do Professor Shaw's papers inform your understanding of EE and CS education at Polytechnic during the 1970s-1990s?

2.) According to the items in the Shaw collection, does there seem to be a shift in EE and CS education at Polytechnic over time? Do shifts or stability in technology courses say something about technology in the field?

3.) Are there holes in the collection (archival silences) that could impact the way you interpret this collection? Is there information you wish was included in the collection?

4.) Henry Jasik Papers
http://dlib.nyu.edu/findingaids/html/poly/jasik/

Biographical/Historical Note:

Henry Jasik (1919-1977) received a BS in Electrical Engineering from Newark College of Engineering in 1938, a Master of Electrical Engineering from Polytechnic Institute of Brooklyn in 1951 and a Doctor of Electrical Engineering from Polytechnic Institute of Brooklyn in 1953.

After he graduated from Newark College of Engineering, Jasik worked for the Navy and the Civil Aeronautics Administration, assisting with radio aids to air navigation and airborne radar and communications antennas. After some time as an independent consultant and completing his graduate work at the Polytechnic Institute of Brooklyn, Jasik founded Jasik Laboratories, Inc. in 1955. His company focused on the design, manufacture, and testing of various antenna types. Jasik was elected a Fellow of the Institute of Electrical and Electronic Engineers in 1958 for his contributions to "the theory and design of VHP and microwave antennas." Jasik's *Antenna Engineering Handbook* was first published in 1961 and is still widely referenced today.

Source: "Dedication." Antenna Engineering Handbook: Third Edition, Richard Johnson, ed., McGraw-Hill, New York, 1993.

Research Questions:

1.) Dr. Jasik edited a widely referenced handbook for antenna engineers. What might his collection of notebooks and photographs of antennas add to a technological understanding of 20th century antenna technology that is not captured in the handbook?

2.) How do primary source materials in the Jasik collection enhance or complicate your understanding of the development of technology in the twentieth century?

3.) The Jasik Papers contain different format types: notes, reports, photographs, etc. How do these materials come together to create a historical narrative? Alternatively, what is missing from the collection (archival silences) that could help to bridge together different types of primary source materials?

5.) Herman Mark Papers (RG.002)
http://dlib.nyu.edu/findingaids/html/poly/hmark/

Biographical / Historical note

Herman Francis Mark, The Father of Polymer Science, was born in Vienna on May 3, 1895. Although his schooling was interrupted by World War I, in which he served on the front lines as well as spending a year as a prisoner of war, he managed to complete his doctoral dissertation on the synthesis and characterization of the pentaphenyl ethyl free radical. His doctoral advisor, Wilhelm Schlenk, subsequently offered Mark a position at the University of Berlin in 1921.

Mark's position at the university had barely begun when he was offered a job at the Institute for Fiber Research at the Kaiser Wilhelm Institute. Here he worked on projects including x-ray crystallographic, refraction, and polarization studies. In 1926 he took a position at I.G. Farbenindustrie to study the production of synthetic fibers. At the start of World War II, he sought employment outside of Germany, becoming a professor of chemistry at the University of Vienna in 1932. There he designed a curriculum in polymer chemistry.

With the Nazi threat looming, Mark and his family prepared to escape Europe by covertly buying bits of platinum wire and twisting it into coat hangers in order to accumulate money for travel and a new life. By the time the Mark family escaped to Canada, they had amassed $50,000 in platinum wire.

Herman Mark joined the Polytechnic Institute of Brooklyn (PIB) as an adjunct professor in 1940. Mark's position at PIB, as well as his relationships with DuPont and the wartime Office of Scientific Research and Development, led to further development in his polymer research. In 1947, the Institute of Polymer Research was founded at PIB; the first graduate program of its kind in America. Mark continued his relationship with PIB for over 50 years. He died in 1992.

The discipline of polymer science that Mark helped to establish is now a vital branch of chemistry. Polymers, macromolecules formed synthetically by uniting monomers, have high viscosity, elasticity, and strength. The first synthetic fiber, nylon, was a result of Mark's work in polymers. Today many scientific companies conduct polymer research.

Focus: Box 6: Series II: Correspondence, Subseries A: Personal and Subseries B: Professional

Research Questions:

1.) How might a scientist's correspondence (professional and personal) be important to understanding the development of science or technology?

2.) How does looking at just one section of a large collection impact the way you understand the subject of the collection? Are you able to make educated guesses about a scientist or technological innovation from viewing just one series of a collection?

3.) What complications are there in understanding Mark's correspondence? What is missing (archival silences) that could help to illuminate your understanding?

6.) Frank E. Canavaciol Papers (RG.010)

http://dlib.nyu.edu/findingaids/html/poly/canavaciol/

Biographical / Historical note

Frank E. Canavaciol was an instructor of electrical engineering at Polytechnic from 1916 until 1966. He taught a variety of classes in the Electrical Engineering Department, ranging from entry-level 401 and 402 classes to upper level classes. During his time at Polytechnic, he also co-authored a book on the topic of Radio Phone Receiving in 1922, and was an active participant in the Professional Engineering Licensing Exams, helping to both write and review electrical engineering questions. He died in Queens in May of 1987, at the age of 91.

Scope and Contents note

This collection consists primarily of lecture notes, homework problems, and lab experiments from classes taught by Canavaciol from the mid-1930s through the 1950s. During his time at Polytechnic, Canavaciol also submitted and reviewed questions for the Professional Engineer Licensing Exam and his sample questions, answers, original test booklets, and records of his involvement from 1947- 1962 are also present. The collection also contains related literature from Canavaciol's library, primarily reprints, brochures, and manuals from companies such as AT&T, RCA, and General Electric, though there are also some larger volumes, including a course book from an extension course offered by Westinghouse. Lastly, wire samples from the Sensitive Research Instruments Corporation are also included.

Research Questions:

1.) How do Professor Canavaciol's EE lecture notes inform the way you think of the development of electrical engineering in the United States?

2.) According to the items in the Canavaciol collection, does there seem to be a shift in EE education at Polytechnic over time? Do shifts or stability in technology courses say something about technology in the field?

3.) Are there holes in the collection (archival silences) that could impact the way you interpret this collection? Is there information you wish was included in the collection?

7.) Kenneth Wyatt (RG.023)

http://dlib.nyu.edu/findingaids/html/poly/wyatt/

Biographical / Historical note

Kenneth Sapwell Wyatt was born in Cambridge, Massachusetts in 1900. After two years of engineering studies at Mount Allison University in New Brunswick, Canada, he majored in physical chemistry and graduated in 1921 with a B.A. He earned a B.Sc. with honors in chemistry in 1922. After a year of graduate work at Harvard University, he became an assistant research chemist for the Carborundum Company in Niagara Falls, New York. He received a scholarship from the National Research Council of Canada and attended the University of Toronto in 1923. In 1961, Mount Allison University awarded him the degree of doctor of science, Honoris Causa.

Wyatt joined the research department of the Detroit Edison Company in 1928 and specialized in the study of the deterioration of high voltage insulation. During the 1930s, Wyatt was the technical director of Enfield Cable Works in London. In 1941, he became a consultant to the Phelps Dodge Copper Products Company of New York; a position that would last until his retirement in 1964.

Over the course of his career, Wyatt worked with polymer scientists, such as Brooklyn Polytechnic Institute's Herman Mark and Frederick Eirich, and electrical engineers to develop extra-high voltage cables, capable of insulating 500,000 volts. He was a member of the Edison metal committee of the Institute, the American Chemical Society (ACS), and the American Institute of Electrical Engineers (AIEE). In 1933, Wyatt and his co-authors W.E. Spring and C.H. Fellows, were awarded the A.I.E.E. national prize for initial paper for the contribution "A New Method of Investigating Cable Deterioration and Its Application to Service Aged Cable." Wyatt died in Dobbs Ferry, NY on January 15, 1967.

Research Questions:

1.) How do primary source materials in the Wyatt collection enhance or complicate your understanding of the development of technology in the twentieth century?

2.) How might a scientist's correspondence be important to understanding the development of science or technology?

3.) The Wyatt Papers contain many different format types: correspondence, patents, reports, blueprints, maps, clippings, etc. How do these materials come together to create a historical narrative? Alternatively, what is missing from the collection (archival silences) that could help to bridge together different types of primary source materials?

8.) Judith Bregman Film Collection (RG.013)

http://dlib.nyu.edu/findingaids/html/poly/bregman/

Biographical / Historical note

Judith Bregman was a professor of Physics at Polytechnic Institute of New York from 1957 until her death in 1978. A graduate of Bryn Mawr and Cornell University, Bregman specialized in the areas of physical chemistry, x-ray crystallography, electron diffraction, and light scattering. During her time at Poly, she developed an interest in the preparation of instructional films, and is perhaps most well-known for her film 'Symmetry', which was created in 1966 in cooperation with Alan Holden, Richard Davisson, and Philip Stapp. The film received much attention, and was even shown at the Museum of Modern Art. She also participated in the making of other films, such as 'Aspects of Symmetry'. She died of cancer on October 2, 1978 at the age of 57.

Scope and Contents note

This collection consists largely of the 16mm films which comprised Bregman's personal "film library" in the Physics Department at NYU-Poly. Included are 35 films of varying length and content; the some in color and some with audio. A number of the films, the ones to be found in Subseries A, were created by or for Polytechnic with the help of Bregman herself; the most notable of these is Symmetry. The remainder are films used by Bregman for class instruction and cover topics such as crystallography, quantum mechanics, and light scattering.

The collection also contains five film reel shipping containers in which the films were originally stored. The films are also accompanied by correspondence, grant proposals and contracts, reviews and articles of the films, film stills from Symmetry, documents from the Bergman Film Library account, and biographical materials about Bregman.

Research Questions:

1.) Analyze Bregman's use of technology in her physics films.

2.) What do Bregman's teaching films "Symmetry" and "Aspects of Symmetry" say about the methods and techniques of disseminating scientific knowledge in the 1970s in the United States?

3.) Are there holes in the collection (archival silences) that could impact the way you interpret this collection? Is there information you wish was included in the collection?